Defense Technical Information Center Compilation Part Notice

ADP010731

TITLE: Dynamic Stall Data for 2-D and 3-D Test Cases

DISTRIBUTION: Approved for public release, distribution unlimited

This paper is part of the following report:

TITLE: Verification and Validation Data for Computational Unsteady Aerodynamics [Donnees de verification et de valadation pour l'aerodynamique instationnaire numerique]

To order the complete compilation report, use: ADA390566

The component part is provided here to allow users access to individually authored sections of proceedings, annals, symposia, ect. However, the component should be considered within the context of the overall compilation report and not as a stand-alone technical report.

The following component part numbers comprise the compilation report:
ADP010704 thru ADP010735

22-E. DYNAMIC STALL DATA FOR 2-D AND 3-D TEST CASES

Professor R A McD Galbraith
Dr F N Coton
Dr R B Green
Dr M Vezza

University of Glasgow

INTRODUCTION

Background

Although substantial work has been carried out and much understanding gained of the phenomena associated with dynamic stall, our description and understanding of it is incomplete. Even if we consider the nominally two-dimensional flow associated with most experiments, some significant anomalies have yet to be explained. Fully three-dimensional experiments are few and, as might have been expected, raise more questions than have been answered.

The purpose of the selected cases herein is to provide the computational fluid dynamic specialists with a variety of test data to assess the output of their codes. The experimentalists may then obtain additional information from the CFD specialists so that together the knowledge and understanding of dynamic stall and the associated anomalies may be enhanced.

As described by Young (ref 1), the nominally two-dimensional case is considered to be characterised by a dynamic overshoot of the aerodynamic coefficients followed by stall onset and the roll-up of the shed vorticity into a coherent vortex that convects over the upper surface of the aerofoil and then off into the mainstream. It is the convection speed of the main vortex (dynamic stall vortex) in which a distinctive anomaly has been identified by Green et al (ref 2). It was observed that certain data indicated an independence of the convection speed from the motion of the model, whilst others did not. (see Fig 1). Of all the influencing factors that could have contributed to that clear difference of result, such as aerofoil shape, aspect ratio, surface finish, data reduction software and Mach number, all but the Mach number had no effect on the observed trends. Green and Galbraith concluded (ref 3) that the most likely contender causing the two very different results would be the difference in the Mach number between the experimental set-ups. Albeit the data sets contained in section 1 are for low Mach numbers (M = 0.12) they do cover a wide range of reduced pitch rate. If CFD results reproduce the constancy of "stall vortex" convection speed observed, then it would be helpful to recalculate for a few higher Mach numbers; say, 0.2, 0.4 and 0.7.

Although the Glasgow data (covering 14 different models) indicated an independence of convection speed with regard to the reduced pitch rate and the reduced frequency, there was a variation between different models. It was observed, however, (ref 2 and 3) that the speed did appear to be dependent on the shape of the aerofoil and the method of transition. It appeared that, if a transition strip was placed at the leading edge (consisting of filtered grit) then the convection speed was reduced and, similarly, the scatter (ref 4). Suitably "tripped" data are contained in section 2.

Section 2 presents data from two NACA 0015 aerofoils of different aspect ratio. It is hoped that the spread of test cases can be used to assess the quality of prediction of low-speed dynamic stall. The data are for motions of "ramp-up", "ramp-down" and oscillatory pitch. Both the ramp-up and ramp-down are important because they isolate the stalling mechanisms from the re-attachment process. As such, the mix, where the aerofoil is simultaneously attempting to stall and "re-attach", during some oscillatory modes, is absent.

In addition, the ramp-downs will provide a most interesting case because the data clearly show that, at the high pitch rates, one can achieve negative lift at high incidence. Figure 2 shows the effect of pitch rate upon the normal force during ramp-down tests of the Sikorsky SSC-A09 aerofoil. Although this was not the most severe case, it does indicate (see Fig 2) that it has negative lift at incidence as high as 8 degrees; other, uncambered aerofoils produced negative lift at incidences as high as 10 degrees.

Both the NACA 0015 aerofoils are for a nominally two-dimensional test set-up, although, at least for the steady case, the flows are likely to be highly three-dimensional in the stall condition. Nonetheless, the data are very comparable and show very similar trends, especially in the ramp-down motion. The only significant difference between the high aspect and the low aspect ratio models is, of course, the Reynolds number. This manifests itself in the ramp-down mode only in the latter stages of re-attachment. This is a consequence of the Reynolds number effects on the boundary layer.

The section 3 data from a finite wing with a NACA 0015 section is presented and provides a very severe test case for any current CFD code.

Summary of Test Cases

All of the models referred to herein were tested for the following motion types: static, linear ramp-up, linear ramp-down and sinusoidal. Actual test cases presented in the following sections are summarised in table 1.

NOMENCLATURE

c	chord (m)
Cm	pitching moment coefficient (ref point 1/4c)
Cn	normal force coefficient
Cp	pressure coefficient
Ct	thrust coefficient (+ve towards leading edge)
DP	dynamic pressure (N/m^2)
g	acceleration due to gravity (m/s^2)
k	reduced frequency $\left(\omega c/2U\right)$
M	Mach number
r	reduced pitch rate $\left(\frac{\partial \alpha}{\partial t} c/2U\right)$
Re	Reynolds No $\left(\frac{Uc}{\nu}\right)$
s	span (m)
x	chordwise direction (m)
y	direction normal to chord (m)
z	spanwise direction (m)
U	velocity (m/s)

angle of attack (degrees)

ν	kinematic viscosity (m/s)
ω	rotational frequency (rads/s)